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SOIL TESTS OF ERICACEAE AND OTHER REACTION-SENSITIVE FAMILIES IN NORTHERN VERMONT AND NEW HAMPSHIRE

EDGAR T. WHERRY

THE relative importance of physical and chemical features of soils in determining the distribution of vegetation is the subject of considerable difference of opinion. Some have reached the conclusion that physical factors, such as porosity and water content, are more significant than chemical factors, such as the presence of abundant lime or of excessive acidic substances; others consider the chemical nature of the soil, and accordingly the nature of the rock from which it is derived, to be of fundamental importance. An illustration of the application of these two viewpoints in explaining the distribution of two northern coniferous trees has recently been published by Fernald.[1] The physical features proved in these cases entirely inadequate to account for the observed relationships, whereas the geology, and the resultant chemical properties of the soil, show so close a correlation with the areas occupied by the species in question, that no one approaching the subject with open mind could fail to recognize therein the dominant factor in their distribution.

The writer became interested in this subject several years ago, while engaged in geological field work in Pennsylvania, through observing that relationships existed between the native plants and the underlying rock formations; but at that time there was no simple method available to determine whether the effect was chiefly physi-

[1] Fernald, M. L. Lithological factors limiting the ranges of *Pinus Banksiana* and *Thuja occidentalis*. RHODORA xxi. 41 (1919).

cal or chiefly chemical. The subsequent demonstration by Gillespie[1] that the reaction (acidity or alkalinity) of a soil can be directly measured by the use of indicators—that is, dyes which change their colors with variations in reaction furnished a means for obtaining definite information upon the matter. The method was first tried out in the laboratory, on soil samples representing various geological formations as well as different species of plants which were supposed to be sensitive to soil reaction; and the preliminary results on one group, the *Orchidaceae*, have already been published.[2] The method was later modified for use in the field, as recently described.[3] On learning of this method, Mr. Frederick V. Coville of the Bureau of Plant Industry, U. S. Department of Agriculture, suggested to the writer that since the *Ericaceae* are apparently especially sensitive to soil reaction—for the most part requiring definite acidity—it would be desirable that tests be made on a number of members of this family. Accordingly, with the aid of funds from the Bureau of Plant Industry, several trips were taken for this purpose; and in the present paper are recorded the results obtained on one of these trips in June, 1919, at certain points in northern New England. While the *Ericaceae* were studied primarily, data were obtained on other plants growing in the same regions; although only plants which for one reason or another are inferred to be decidedly sensitive to soil reaction are considered, and no attempt is made to list all the species growing in the places visited. The nomenclature of Gray's Manual, 7th edition, 1908, is followed throughout, synonyms being introduced in certain cases. Pressed specimens of the plants studied have been deposited in the U. S. National Herbarium.

The acidity and alkalinity of the soils studied are described in terms recommended for the purpose elsewhere.[4] To summarize the plan here, omitting technical physical-chemical terms,—pure water, which is neutral in that equivalent amounts of acid and alkaline constituents (ions) are present in it, is taken as the unit of both "specific acidity" and "specific alkalinity." A solution containing up to 10

[1] Gillespie, L. J. The reaction of soil and measurements of hydrogen-ion concentration. Journ. Wash. Acad. Sci. vi. 7 (1916).

[2] Wherry, Edgar T. The reactions of the soils supporting the growth of certain native orchids. Journ. Wash. Acad. Sci., viii. 589 (1918).

[3] Wherry, Edgar T. Determining soil acidity and alkalinity by indicators in the field. Jorn. Wash. Acad. Sci., x. (April, 1920).

[4] Wherry, Edgar T. The statement of acidity and alkalinity, with special reference to soils. Journ. Wash. Acad. Sci., ix. 305 (1919).

times as much acid as is contained by water is called "minimacid;" one containing from 10 to 100 times, "subacid;" from 100 to 1000 times, "mediacid;" and more than 1000 times, "superacid." Corresponding terms are used on the alkaline side, although medialkaline and superalkaline soils are not known to exist in the eastern United States, to which these studies are confined. It is sometimes convenient to group together minimacid, neutral and minimalkaline soils under the term, "circumneutral."

As to the correspondence between these and previously used terms, —"oxylophytes," as defined by Warming and others, seem to be characteristic of soils possessing only the higher degrees of acidity as here classified. "Calciphiles" or "calcicoles" may grow in soils of widely varying reaction, for calcium often exists in soils in the form of neutral salts, such as the sulphate and the chloride. However, since a very abundant compound of calcium, the bicarbonate, yields an alkaline reaction, calcicoles are particularly frequent in alkaline soils. These relations are brought out in the following table:

Table I. Comparison of Common Soil Reactions and Plant Types.

Reaction	Mediacid	Subacid	Minimacid	Neutral	Minimalkaline
			Circumneutral		
Calcium Salts	Insoluble	Sulphate, chloride, etc.			Bicarbonate
Oxylophytes	Common	Occasional	Rare	Absent	Absent
Calcicoles	Absent	Rare	Occasional	Common	Common

For practical purposes, then, oxylophytes may be regarded as plants characteristic of mediacid soils, and calcicoles of circumneutral soils.

The tests are made by stirring up a soil with neutral water, pouring off the more or less clear liquid, and adding a drop or two of appropriate indicator solution. From the color then assumed the specific acidity or alkalinity of the soil in question can be determined. Sets of indicator solutions arranged for use in the field, with directions for their application, can now be purchased. (See advertising columns of this journal).

Every species of plant has of course an acid and an alkaline limit to its growth; and if these are sufficiently wide apart the plant may be regarded as indifferent to soil reaction. In the *Ericaceae* and other families here studied, however, it has been found that not only do these limits lie fairly close together, but also that for different species the limits have characteristically different positions in the scale. When these points are considered, in connection with the fact that in many cases a given species grows under the most widely varying physical conditions, from the wettest bogs to the driest sandy uplands, the conclusion can hardly be avoided that the chemical features of the soil are of greater significance than the physical ones in determining the distribution of these plants.

It has been found that in certain nurseries ericaceous plants can be grown in soils with an initial acidity distinctly below the lowest limits observed for the same species in nature. This is no doubt due partly to the exclusion of competition and partly to the fact that vigorous plants develop increased acidity immediately around their roots. However this may be, the limiting reactions shown by the soils supporting each species in its natural habitats are well worth determining. It is not claimed that the soil reaction is the only factor controlling the distribution of these plants; nor is the manner in which the reaction affects the plant considered. The aim of this paper is essentially to record observational data as to the reactions shown by the soils in typical natural occurrences of *Ericaceae*. It is hoped that these data can be supplemented by future work in other regions.

The regions in which the studies have been made, the general features of the soils there, etc., are presented in Table II. Detailed descriptions of the distribution of plants and soils follow.

TABLE II. FEATURES OF REGIONS STUDIED.

Region	State	Surface Formation	Soil	Dominant Reaction	Ericaceae
Summits of White Mountains	N. H.	Gneiss, granite	Black alpine peat	Mediacid	Abundant
Mountains along Willoughby Lake	Vt.	Calcareous drift	Upland peat	Circumneutral	Rare
Swamps, etc., south of Willoughby Lake	Vt.	Calcareous drift	Peat and muck	Subacid	Common
Bog south of West Burke	Vt.	Siliceous drift	Peat	Mediacid	Abundant
Swamps, etc., St. Johnsbury and Fairlee	Vt.	Varied drift	Peat and muck	Subacid	Common

Grateful acknowledgment is herewith made to Miss Inez A. Howe, of the Fairbanks Museum, St. Johnsbury, and to Rev. Dr. H.

M. Denslow, at the time residing at Fairlee, who acted as guides to the Vermont localities; to Messrs. Edward and Kenneth Gillett, who demonstrated how they grow native plants in their nursery at Southwick, Massachusetts; and to Harry W. Trudell and Louis H. Koch, who took part in the expedition as voluntary associates, and aided materially in collecting the data.

Summits of the White Mountains, New Hampshire.

The flora of the White Mountains has been described by Flint,[1] by Grout[2] and by Fernald.[3] The underlying rock is dominantly mica gneiss, with considerable granitic intrusions and quartz veins.

The first few hundred feet of ascent of the Presidential Range is through the spruce-fir forest, where the upland peat is mostly subacid in reaction, and ericaceous plants are rare, only *Chiogenes hispidula* and *Vaccinium canadense* being noted. At about 1200 meters elevation the conifers become smaller in stature, the soils blacker and more acid, and *Ericaceae* more abundant, *Rhododendron* (*Rhodora*) *canadense* and *Vaccinium pennsylvanicum* var. *angustifolium* appearing at the upper limit of trees. Above the tree line the ground is carpeted by vast numbers of ericaceous plants, growing in autogenous, black, damp or even wet humus, which may be designated for convenience as "alpine peat." Here were found, in addition to those already listed: *Ledum groenlandicum, Kalmia angustifolia, Kalmia polifolia, Arctostaphylos alpina, Vaccinium uliginosum, V. Vitis-Idaea* var. *minus,* and the heath-like *Empetrum nigrum.* In occasional colonies of sphagnum *Vaccinium Oxycoccos* was also found. On the rocky ledges, in similar but somewhat drier soil, besides many of the above list, were observed: *Loiseleuria* (*Chamaecistus*) *procumbens, Phyllodoce coerulea, Cassiope* (*Harrimanella*) *hypnoides, Vaccinium caespitosum,* and the pubescent *Empetrum atropurpureum* (*E. nigrum* var. *andinum* of the Manual). The alpine peat supporting all of these species showed uniformly mediacid reaction. Only exceptionally were lower values, down to subacid, observed, where occasional colonies of the same species had spread down into the upland peat of the forest floor. One species reported from the region, *Andromeda*

[1] Flint, W. F. The distribution of plants in New Hampshire. In: Geology of New Hampshire, by C. H. Hitchcock, i. 381 (1874).

[2] Grout, A. J. A botanist's day on Mt. Washington. Plant World ii. 116 (1899).

[3] Fernald, M. L. The soil preferences of certain alpine and subalpine plants. Rhodora ix, 149 (1907).

glaucophylla, could not be found, but its soils are no doubt similar in reaction.

In the most exposed places of all, near the summits of the mountains, the soil consists chiefly of frost-broken rock fragments, and even these *Ericaceae* are unable to gain much foothold. *Rhododendron lapponicum* and *Diapensia lapponica* are typically developed in this sort of situation, along with scattered colonies of the other species. The crumbling rock itself, where as free as possible from organic matter, ranges in reaction from subacid to neutral, the acidity being apparently due to the presence of minute lichens, etc.; but on testing the material at the roots of the plants mentioned, a mediacid reaction was almost invariably obtained, because of the presence of humus mixed with the rock fragments. Seedlings of these plants were occasionally found in material of lower acidity, but the reaction around them is never less than subacid.

The distribution of plants of other groups with reference to the soil acidity is also a matter of interest. Among ferns, the absence of the usual rock-growing species, such as the Woodsias and true Aspleniums, is a striking feature, the soils apparently being too acid for these. Three specimens of ferns were noted above the tree-line, in mediacid alpine peat on rocky ledges: *Phegopteris polypodioides* (*Phegopteris*), *Aspidium* (*Dryopteris*) *spinulosum*, *Asplenium Filix-femina* (*Athyrium angustum*). These ascend to very high elevations, the last reaching practically to the summit of Mt. Washington itself (1917 meters), although all are considerably dwarfed. *Lycopodium Selago* var. *appressum* and *L. annotinum* var. *pungens* appear in the most exposed situations, the soils being likewise mediacid or rarely subacid.

Of flowering plants other than *Ericaceae*, the following are noteworthy. In damp soils of mediacid reactions grow *Streptopus roseus*, *Coptis trifolia*, *Trientalis americana*, and *Lonicera caerulea* var. *villosa*. In drier, though not the most exposed places, grow also *Maianthemum canadense*, *Clintonia borealis*, and *Cornus canadensis*. In the bare rocky ground, where *Diapensia* flourishes, occur *Salix Uva-ursi*, *Arenaria groenlandica*, *Stellaria borealis*, *Potentilla tridentata* and *Geum* (*Sieversia*) *Peckii;* the *Stellaria* and a grass, *Poa laxa*, being the only plants observed at the actual summit of Mt. Washington. The soils of all these species proved to be normally mediacid in reaction.

Soils of minimacid reaction were found to occur on the White Mountains only in springy places. Ericaceous plants were in no case observed in such material, but a few species elsewhere found in soils of low acidity were noted, such as *Habenaria* (*Limnorchis*) *dilatata, Habenaria* (*Lysiella*) *obtusata* and *Castilleja pallida* var. *septentrionalis.*

Willoughby Lake, Vermont

The Willoughby Lake region is well known to botanists, especially from the excellent Flora published by Kennedy[1] in which previous work is summarized. Fernald[2] has discussed contrasts shown by the plants of this region and those of certain other localities in New England and adjacent Canada. The rock of Mts. Willoughby and Hor, Ordovician in age, is dominantly gneissic in character, with many calcareous strata, as well as granitic intrusions. The spring water seeping out from the faces of the cliffs has in practically every case traversed more or less limy material, and proved to be slightly alkaline in reaction; in rare instances it is neutral. The talus slope contains abundant calcareous rock fragments and its soils are mostly circumneutral in reaction. On the mountain slopes the soils vary in reaction, being circumneutral where the calcareous strata outcrop, although there are also minor areas of acid soils over granite ledges, as well as in places where thick upland peat has developed.

Few plants usually regarded as characteristic of acid soils are present in the Willoughby region. Colonies of *Cornus canadensis* occur on some of the acidic areas, and two acid-soil orchids, *Habenaria* (*Coeloglossum*) *bracteata* and *Habenaria fimbriata* (*grandiflora*) were noted in upland peat on the north slope of Mt. Willoughby. The only ericaceous plants seen on the whole mountain were a few members of the *Pyrola* group: *Chimaphila umbellata, Pyrola asarifolia, P. chlorantha, P. elliptica,* and *P. secunda.* All these grow in upland peat ranging from subacid to neutral in reaction.

Of plants usually found in limestone regions, and presumably partial to alkaline soils, the following are noteworthy: *Asplenium Ruta-muraria, Cryptogramma Stelleri, Woodsia glabella; Parnassia caroliniana, Saxifraga oppositifolia, S. Aizoon, S. aizoides,* and *Primula mistassinica.* Their soils were found to range from circumneutral to subalkaline.

South of Willoughby Lake conditions are entirely different. During the Glacial Period the ice advanced southward between Mts.

[1] Kennedy, G. G. The Flora of Willoughby, Vermont. Rhodora, vi. 93 (1904).
[2] Rhodora, ix, 149 (1907).

Willoughby and Hor, removing vast quantities of the rocks of which they are composed, and spreading this material over lowlands to the south for a distance of many miles. The rocks are, as previously noted, distinctly calcareous, and accordingly the springs which emerge from the hummocks of glacial drift are for the most part more or less alkaline in reaction. Acid soils have developed here and there wherever the decomposing vegetable matter has formed layers of sufficient thickness to prevent neutralization by the alkaline rock constituents.

The water in depressions in the cool dark arbor vitae (*Thuja occidentalis*) swamps is throughout slightly alkaline. No ericaceous plants were observed to grow in this water, although several orchids do so, notably *Cypripedium hirsutum* (*reginae*), *Listera convallarioides*, *L. cordata*, *Habenaria* (*Limnorchis*) *hyperborea*, *H. dilatata* (in open places), and *Corallorrhiza trifida.* On the hummocks of peaty material, however, several *Ericaceae* were noted, including *Pyrola secunda* var. *obtusata*, *P. asarifolia* var. *incarnata*, *Moneses uniflora*, *Vaccinium canadense*, and *Chiogenes hispidula*, in subacid or more often mediacid soil. Orchids which stick to the more acid soil situations are *Habenaria* (*Lysias*) *orbiculata*, *Epipactis repens* var. *ophioides*, *E. tesselata*, and *Corallorrhiza maculata.* The bunchberry, *Cornus canadensis*, is also limited to the acid locations.

The streams which rise on the south side of the col below the head (south end) of Willoughby Lake have minimalkaline to subalkaline water, and the relations shown by the plant associations surrounding them are noteworthy. *Myrica Gale* grows directly in the alkaline water, but although some ericaceous shrubs appear to accompany it closely, actual tests of the soil around their roots showed distinct to marked acidity in every case. The boldest of these, *Chamaedaphne calyculata*, occasionally reaches out as far as material of minimacid reaction; but *Kalmia angustifolia*, *K. polifolia*, and *Ledum groenlandicum* are always in subacid to mediacid peat. Upland peat with subacid reaction on the slopes of the hummocks of drift supports *Epigaea repens*, *Pyrola americana*, and *Vaccinium canadense;* also the orchid, *Habenaria* (*Coeloglossum*) *bracteata*, and such plants as *Linnaea borealis* var. *americana*, and *Cornus canadensis*.

West Burke, Vermont.

A small bog about three miles south of West Burke furnished an instructive contrast to those to the north, which have just been described. Here the drift is non-calcareous, and the open water mediacid. The *Ericaceae* grow far out into the water, forming with the sphagnum a floating mat which quivers under one's steps. *Andromeda glaucophylla, Kalmia angustifolia, K. polifolia,* and *Ledum groenlandicum* (all but the first also observed in the Willoughby region), are abundant here. In the sphagnum grow also *Vaccinium Oxycoccos* and its variety *intermedium* and *Chiogenes hispidula;* and on the drier banks *Pyrola elliptica, Epigaea repens, Gaultheria procumbens,* and *Vaccinium canadense.* In addition to *Ericaceae, Smilacina trifolia, Pogonia ophioglossoides,* and *Sarracenia purpurea* were noted. The soils are practically all mediacid.

It seemed worth while, having indicators on the spot, to test out the correctness of Fernald's[1] remarks as to the habitat of *Thuja occidentalis:*

"It is therefore premature to say that in the region of its almost continuous occurrence . . . *Thuja* confines itself to calcareous soils, for, like many other plants in the area where they are dominant, *Thuja* may prove to be ubiquitous or somewhat indifferent to moderate differences of soil."

As above noted, the water of the *Thuja* swamps is usually found on testing to be somewhat alkaline, the alkaline constituent being of course chiefly calcium bicarbonate, so that the term calcareous is correctly applied. Search was made for occurrences of *Thuja* elsewhere than in swamps, in the same general region. Along the railroad north of West Burke station this tree was found to be growing well, and to be producing some seedlings, in dry sandy drift which has in places a subacid reaction, although it varies from this through minimacid down to neutral. In other parts of Vermont similar observations were made, so that Fernald's statement, based chiefly upon inferences from geological maps, is abundantly confirmed when actual chemical tests are applied.

St. Johnsbury, Vermont.

In the course of the trip there were several opportunities to make tests of the soils in the vicinity of St. Johnsbury, and to obtain data on species of *Ericaceae* and other groups not well represented in the previously described regions. In a *Thuja* swamp about 3 km. east of the town the water was found to be minimalkaline, but hummocks of peaty material are present in which the acidity locally becomes

[1] Rhodora, xxi, 57 (1919).

as high as mediacid. The orchids, *Habenaria* (*Limnorchis*) *hyperborea* and *Cypripedium hirsutum* (*reginae*), and also the typical calcareous soil plant, *Parnassia caroliniana*, grow in the alkaline water. *Pyrola secunda* was noted on a hummock with minimacid reaction; while on the more acid ones were found *Aspidium spinulosum*, *A. Boottii*, *Clintonia borealis*, *Cypripedium acaule*, and *Cornus canadensis*, all plants which normally seem to favor highly acid conditions.

In the Knapp swamp, 5 km. west of St. Johnsbury, the conditions proved to be similar to the above. The water ranges from minimacid to neutral, and down in moss saturated with this water and sharing its reaction grow sparingly the rare orchids, *Cypripedium arietinum* and *Calypso bulbosa*, which can thus be classed, on the basis of actual test, as species of circumneutral soil. Three ericaceous plants, *Pyrola secunda* var. *obtusata*, *Moneses uniflora* and *Ledum groenlandicum* grow here, in hummocks with minimacid reaction, and the orchid, *Cypripedium parviflorum*, is abundant in muck with the same acidity. At one point a colony of *Cornus canadensis* was noted within 10 centimeters of the *Calypso*-bearing moss, which suggested that it might at times withstand minimacid conditions; but actual test showed it to have around its roots subacid material: thus the acidity may vary 10-fold or more within a few centimeters, and the vegetation develop accordingly. In pine woods around this swamp the orchids, *Cypripedium arietinum*, *Epipactis tesselata*, and *Habenaria* (*Lysias*) *Hookeri* are abundantly developed, and their soils, representing acid upland peat partially neutralized by underlying calcareous glacial drift, show subacid to minimacid reactions.

In a swamp in the town of Peacham, further west, the conditions are not unlike those just described, but the flora is even richer. Here the water was found to be neutral to minimalkaline, and in it grows *Caltha palustris*, which usually seeks circumneutral waters. In muck with minimacid reaction was noted *Smilacina stellata*, and the tall *Habenarias*. Hummocks of sphagnum are here prominent and, as they possess the usual mediacid reaction, a number of *Ericaceae* grow upon them. The beautiful pink *Pyrola asarifolia* var. *incarnata* (*P. uliginosa* of some authors) is abundant in this situation, the acidity of its soil thus contrasting sharply with that of the typical form of the species, which, as noted in the description of Lake Willoughby, grows there in neutral soil. Others noted are *Pyrola secunda* var. *obtusata, Moneses uniflora, Ledum groenlandicum, Chamaedaphne calyculata, Chiogenes hispidula,* and *Vaccinium Oxycoccos.* In addition to *Ericaceae,* there occur on the sphagnum *Arethusa bulbosa, Listera cordata, Microstylis unifolia, Dalibarda repens, Cornus canadensis, Menyanthes trifoliata,* and *Linnaea borealis* var. *americana,* a typical acid-soil list. By way of contrast, on the same trip, the other species of the orchid genus *Microstylis, M. monophyllos,* was found, near Harvey's Pond, growing in spring water with minimalkaline reaction.

Fairlee, Vermont.

The hills to the west of Lake Morey, near Fairlee station, yielded further interesting results. No arbor-vitae swamps occur here, but there are several swampy spots in the deciduous woods, where the water, emerging from shale strata, is neutral to minimacid in reaction. In this water were found the orchids, *Cypripedium hirsutum* (*reginae*), *Habenaria psycodes, Habenaria* (*Limnorchis*) *hyperborea, H. dilatata, H. dilatata* var. *media, Habenaria* (*Lysiella*) *obtusata, Microstylis monophyllos, Liparis Loeselii,* and *Corallorrhiza trifida.* In drier places, where the acidity is mostly subacid, were observed also *Cypripedium parviflorum* var. *pubescens, Habenaria* (*Lysias*) *Hookeri, H. orbiculata, H. macrophylla,* and *Habenaria* (*Coeloglossum*) *bracteata.* Several ericaceous plants accompany these orchids in the dry or damp woods, their soil being an upland peat more or less neutralized by the underlying glacial drift, so that the acidities are unusually low for several species; those noted comprise: *Pyrola americana, P. chlorantha, P. elliptica, P. secunda, Chimaphila umbellata, Epigaea repens, Gaultheria procumbens, Vaccinium pennsylvanicum* var. *angustifolium* and *V. canadense.* These gave tests of subacid to minimacid reaction.

Data on Individual Species.

In order to summarize the data for each species above noted, and to bring out their acid and alkaline limits of growth, some mode of graphic representation is desirable. For this purpose the specific acidities are best ranged horizontally, and the acidities at which the plant has been observed to grow, being marked by x, and the "optimum," at which the species appears to thrive best, distinguished by a capital X. The letter o refers to data obtained by the writer elsewhere in natural habitats, and n is used to indicate observations made in nurseries. When the reactions of a series of species are tabulated in this manner, the relations between them are brought out clearly, as shown in the following table.

Table III. Soil Acidities of Ericaceae and Related Plants.

	Specific Acidities					
	300 Medi-acid	100	30 Sub-acid	10	3 Minim-acid	1 Neu-tral
Pyroloideae						
Chimaphila umbellata (L.) Nutt.	–	x	X	x	–	–
Moneses uniflora (L.) Gray	x	x	X	x	x	–
Pyrola secunda L.	–	x	X	x	–	–
" " var. obtusata Turcz.	x	x	X	x	x	–
" americana Sweet	–	x	X	x	–	–
" chlorantha Swartz	–	–	x	X	x	–
" elliptica Nutt.	–	x	x	X	x	–
" asarifolia Michx.	–	–	–	–	–	X
" " var. incarnata (Fisch.) Fern.	X	–	–	–	–	–
Ericoideae						
Ledum groenlandicum Oeder	X	x	x	n	–	–
Rhododendron canadense (L.) B. S. P. (Rhodora L.)	x	X	x	n	–	–
Rhododendron lapponicum (L.) Wahl.	X	x	–	–	–	o
Loiseleuria procumbens (L.) Desv.	X	x	–	–	–	–
Kalmia polifolia Wang.	X	x	–	n	–	–
" angustifolia L.	X	x	x	n	–	–
Phyllodoce coerulea (L.) Babington	X	x	–	–	–	–
Cassiope hypnoides (L.) D. Don (Harrimanella Coville)	X	x	–	–	–	–
Andromeda glaucophylla Link	X	x	–	n	–	–
Chamaedaphne calyculata (L.) Moench	X	x	x	x	–	–
Epigaea repens L.	x	X	x	n	–	–
Gaultheria procumbens L.	X	x	x	x	–	–
Arctostaphylos alpina (L.) Spreng.	X	x	–	–	–	o
Vaccinoideae						
Chiogenes hispidula (L.) T. & G.	X	x	x	–	–	–
Vaccinium pennsylvanicum Lam. var. angustifolium (Ait.) Gray	X	x	x	n	–	–
Vaccinium canadense Kalm	x	x	X	x	–	–
" uliginosum L.	X	x	–	–	–	–
" caespitosum Michx.	x	X	x	–	–	o
" Vitis-Idaea L. var. minus Lodd.	X	x	-	n	–	–
" Oxycoccos L.	X	–	–	–	–	–
" " var. intermedium Gray	X	–	–	–	–	–
Diapensiaceae						
Diapensia lapponica L.	X	x	–	–	–	–
Empetraceae						
Empetrum nigrum L.	X	x	–	–	–	–
" atropurpureum Fern. & Wieg. (E. nigrum var. andinum of Gray's Man.)	X	x	–	–	–	–

A number of interesting relationships are brought out by Table III. First of all it is noteworthy that the plants studied fall into two main groups with respect to their optimum reactions, one in which the optimum value is specific acidity 30 or less, the other in which it is 100 or greater. The former corresponds essentially to the *Pyroloideae*, the latter to the *Ericoideae* and *Vaccinoideae*, in the Gray classification.

The range of reaction shown by the members of the *Pyroloideae* is inclined to be rather wide, being from 300 to 3 in a few cases. That they are not by any means indifferent to soil reaction, however, is shown by the fact that the optimum lies in all but the last two cases within the narrow range of specific acidity 10 to 30.

The last two Pyrolas show such a striking contrast in their soil acidity as to warrant special discussion of them. Typical *Pyrola asarifolia* was found growing along Willoughby Lake, in rather dry soil containing calcareous rock fragments, and being throughout practically neutral in reaction. It is also present in certain woods near St. Johnsbury, in damp material of similar reaction. It is, indeed, often classed definitely as a calcicole.[1] On the other hand the variety *incarnata* is abundant in the Peacham swamp, west of St. Johnsbury, growing well up in the hummocks of sphagnum, where the specific acidity is 300; and it was also found in a similar situation in swamps south of Willoughby Lake. Additional observations on both of these plants, and especially on the intermediate forms reported by Fernald,[2] would be desirable to ascertain whether there is any constant and definite correlation between soil acidity and plant characters. Cultivation of these plants in soils of different reactions should also be tried.

In the *Ericoideae* and the *Vaccinoideae*, at least in the series of species here studied, the range of reaction tends to be rather restricted, sometimes being only from 300 to 100, and the optimum reactions all lie within a narrow range. Several of the individual species, however, deserve brief comment. It is curious to note that while *Rhododendron lapponicum* is here found to be a mediacid soil species, and has been recorded by Fernald[3] from several alpine granitic regions, in all of which the reactions are no doubt similar, in northern Sweden

[1] Cf. Blake, S. F. The Flora of New Brunswick. Rhodora, xx. 101 (1918).
[2] Fernald, M. L. Pyrola asarifolia Michx. var. incarnata, n. comb. Rhodora, vi. 178 (1904).
[3] Rhodora, ix, 162 (1907).

it is reported to be "kalkstet" or limited to limestone, and thus presumably to circumneutral soils,[1] as indicated by o in the last column of the table opposite this species. Perhaps different varieties are passing as *Rhododendron lapponicum*, corresponding to the two Pyrolas above discussed, and to *Andromeda glaucophylla* and its circumneutral soil variety *iodandra*.[2]

Loiseleuria (*Chamaecistus*) *procumbens* is stated by Schroeter[3] to grow in the Alps on both crystalline rocks and limestone, but to be surrounded by autogenous humus, so that the soil acidity may be fairly high, even on the latter rock. *Arctostaphylos alpina*, although included by Warming[4] among acid soil plants, is described by Schroeter[5] and by Thompson[6] as growing on limestone. It is possible that it is surrounded by autogenous humus, and that the reaction is acid, or else that another variety is represented. A North American red-fruited form growing on limestone is regarded by Fernald as a distinct species, *Arctostaphylos rubra*.[7] Further study of this group appears to be needed.

Vaccinium caespitosum, though most frequent in acid soil localities, is noted by Fernald[8] to grow in one limestone region, the St. John Valley in Maine and New Brunswick. However, in this, as indeed in the other cases, it would be better to wait for actual soil tests to be made before making deductions as to the soil requirements of these plants. Even in species showing apparently well-defined reactions, it is possible that further work may in some cases lead to the extension of the ranges of reaction as well as the position of the optimum values. The writer expects to continue such work and hopes that others will take it up also, for the more data there are available the more certain will be any conclusions that may be drawn.

In the Acidity 10 column of Table III, the letter n is placed opposite a number of members of the *Ericoideae* and *Vaccinoideae* to indicate

[1] Fries, T. C. E. Botanische Untersuchungen in Nördlichsten Schweden. Upsala 1913, page 230.

[2] Fernald, M. L. A calciphile Variety of Andromeda glaucophylla. Rhodora, xviii. 100 (1916).

[3] Schroeter, C. Das Pflanzenleben der Alpen. Zurich, 1908, page 135.

[4] Warming, E., and Vahl, M. Oecology of Plants (English translation). Oxford, 1909, pp. 211, 213.

[5] Op. cit. p. 158.

[6] Thompson, Harold S. Alpine plants of Europe. London, 1911, p. 183.

[7] Fernald, M. L. The alpine Bearberries and the generic Status of Arctous. Rhodora, xvi. 21 (1914).

[8] Rhodora, ix. 163 (1907).

that they are being temporarily grown in soil of that acidity in Gillett's nursery at Southwick, Massachusetts, although in nature they seem unable to thrive permanently in soils of like reaction.

The results of tests made on soils supporting other groups of reaction-sensitive plants may well be tabulated like the *Ericaceae;* this is done in Tables IV, V, and VI.

TABLE IV. SOIL REACTIONS OF ORCHIDACEAE.

(Observed in northern Vermont and New Hampshire, 1919.)

	Specific Acidities						Spec. Alk,	
	300 Medi-acid	100	30 Sub-acid	10	3 Minim-acid	1 N.	3 Minim-alk.	10
Cypripedium arietinum R. Br.......	–	–	x	X	x	x	–	–
" parviflorum Salisb.....	–	o	x	X	x	o	o	–
" " var. pubescens (Willd.) Knight	–	o	o	X	x	x	o	o
" hirsutum Mill. (reginae)	–	–	–	x	x	X	x	o
" acaule Ait............	X	o	o	o	–	–	–	–
Habenaria hyperborea (L.) R. Br....	–	–	–	x	x	X	x	x
" dilatata (Pursh) Gray....	–	–	–	x	x	X	x	x
" " var. media (Rydb.) Ames...........	–	–	–	–	x	X	x	–
" obtusata (Pursh) Richards	–	x	x	X	x	x	–	–
" Hookeri Torr............	–	x	X	x	–	–	–	–
" orbiculata (Pursh) Torr...	–	x	X	x	–	–	–	–
" macrophylla Goldie......	–	x	X	x	–	–	–	–
" bracteata (Willd.) R. Br..	–	x	X	x	x	–	–	–
" psycodes (L.) Swartz.....	o	o	o	o	X	x	–	–
" fimbriata (Ait.) R. Br.....	–	o	o	X	–	–	–	–
Pogonia ophioglossoides (L.) Ker....	X	o	o	–	–	–	–	–
Arethusa bulbosa L................	X	–	–	–	–	–	–	–
Epipactis repens var. ophioides (Fern.) A. A. Eat......	–	x	X	x	–	–	–	–
" tesselata (Lodd.) A. A. Eat..................	–	x	X	x	–	–	–	–
Listera cordata (L.) R. Br..........	x	x	X	x	x	–	–	–
" convallarioides (Swartz) Torr.	–	–	–	x	X	x	–	–
Corallorrhiza trifida Chatelain......	–	–	–	x	X	x	–	–
" maculata Raf.........	–	x	X	–	–	–	–	–
Microstylis monophyllos (L.) Lindl...	–	–	–	–	x	X	x	–
" unifolia (Michx.) B. S. P.	X	x	o	o	–	–	–	–
Liparis Loeselii (L.) Richard........	o	o	o	o	X	x	–	–
Calypso bulbosa (L.) Oakes.........	–	–	–	x	X	x	–	–

The above list supplements the one previously published by the writer,[1] in which species of more southern distribution were treated, although a few appear in both lists. It is noteworthy that there are among the northern orchids many with greatest development in circumneutral soils, whereas most of the southern species prefer

[1] Journ. Wash. Acad. Sci., viii. 589 (1918).

more acid soils. Divergent measurements obtained on some of the above species elsewhere than in New England are indicated by the letter o in the appropriate column. The range of some species is rather wide, yet even in these cases the optimum usually has characteristic position. It is striking that in certain cases two species of the same genus may diverge widely in optimum soil reaction.

Finally, reaction-sensitive plants, belonging to other than the above two families, which were studied will be listed for completeness. In Table V are given the oxylophytes; the optimum reaction of all these has been found by actual test to be mediacid, although a few of them have been observed occasionally in subacid soils as well.

Table V. Mediacid Soil Plants (Oxylophytes).

(Observed in northern Vermont and New Hampshire, 1919.)

Aspidium Boottii Tuckerman (Dryopteris Boottii Underwood).
" spinulosum (O. F. Müll.) Swartz (Dryopteris spinulosa Kuntze).
" " var. intermedium (Muhl.) D. C. Eat. (Dryopteris intermedia (Willd.) A. Gray).
Lycopodium Selago L. var. appressum Desv.
" annotinum L.
" " var. pungens Desv.
Smilacina trifolia (L.) Desf. (Vagnera trifolia Morong.)
Clintonia borealis (Ait.) Raf.
Streptopus amplexifolius (L.) DC.
" roseus Michx.
Salix Uva-ursi Pursh.
Arenaria groenlandica (Retz.) Spreng.
Stellaria borealis Bigel.
Sarracenia purpurea L.
Coptis trifolia (L.) Salisb.
Rubus Chamaemorus L.
Potentilla tridentata Ait.
Geum Peckii Pursh (Sieversia Peckii R. Br.).
Pyrus melanocarpa (Michx.) Willd. (Aronia Britton).
Cornus canadensis L. (Chamaepericlymenum canadense Aschers. & Graebn.).
Trientalis americana (Pers.) Pursh.
Linnaea borealis L. var. americana (Forbes) Rehder.

In Table VI plants of circumneutral soils as shown by actual tests, are treated similarly; probably all of these are to be classed as calcicoles.

TABLE VI. CIRCUMNEUTRAL SOIL PLANTS (CALCICOLES).

(Observed in northern Vermont and New Hampshire, 1919.)

Cryptogramma Stelleri (Gmel.) Prantl (Pellaea gracilis Hook.).
Cystopteris bulbifera (L.) Bernhardi (Filix bulbifera Underwood).
Woodsia glabella R. Br.
" alpina (Bolton) S. F. Gray (W. hyperborea R. Br.).
Asplenium Ruta-muraria L.
Thuja occidentalis L. (Also in subacid soils high in calcium salts.)
Smilacina stellata Desf. (Vagnera Morong).
Anemone riparia Fernald.
Caltha palustris L.
Braya humilis (C. A. Mey.) Robinson.
Saxifraga Aizoon Jacq.
" aizoides L.
" oppositifolia L.
Parnassia caroliniana Michx.
Astragalus Blakei Eggleston.
Primula mistassinica Michx.
Campanula rotundifolia. (Also in subacid soils high in calcium salts.)

DEPARTMENT OF AGRICULTURE, Washington, D. C.

THE AMERICAN VARIETIES OF PYROLA CHLORANTHA.

M. L. FERNALD.

To one who has been familiar with the large-flowered *Pyrola chlorantha* which occurs in scattered colonies through dry woods of southern New England, southern New York and Pennsylvania, it often seems strange that the smaller-flowered plant of northern New England and adjacent regions is conspecific with it. The common plant of eastern Massachusetts, for example, has numerous rounded leaves which make a conspicuous rosette, the blades often 3–4.5 cm. broad and nearly as long, and the greenish-white petals 6.5–9 mm. long and comparatively broad (3.5–6 mm.). This is the plant described by Barton in 1815 as *P. convoluta.*[1] In the White Mountains and across the northern half of Maine, on the other hand, *P. chlorantha* is often quite leafless or has only a few leaves, these inclined

[1] Barton, Fl. Phil. Prodr. 50 (1815).